(12) LEVEL II

SC

REPORT No. 7905
NOVEMBER 1979

ADA081932

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SLIPS OF THE MIND AND AN OUTLINE FOR A THEORY OF ACTION

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This research was supported by the Advanced Research Projects Agency and the Office of Naval Research, Personnel and Training Research Programs and was monitored by ONR under Contract N00014-79-C-0515NR 157-434 under terms of ARPA Order No. 3767. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Advanced Research Projects Agency, of the Office of Naval Research, or the United States Government.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE — READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 14 7905	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER: 9	
4. TITLE (and Subtitle): 6 Slips of the mind and an outline for a theory of action	5. TYPE OF REPORT & PERIOD COVERED: Technical Report
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): 10 Donald A. Norman	8. CONTRACT OR GRANT NUMBER(s): 15 N00014-79-C-0515, ARPA Order-3767
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Center for Human Information Processing, University of California, San Diego, La Jolla, CA 92093	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: NR 157-434
11. CONTROLLING OFFICE NAME AND ADDRESS: Personnel and Training Research Programs, Office of Naval Research (Code 458), Arlington, VA 22217	12. REPORT DATE: 11 November 1979
	13. NUMBER OF PAGES: 34
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 12 25	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Human factors, human error, slips, accidents, consciousness

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Slips or unintended actions have both theoretical and applied importance, by providing insight into possible underlying mechanisms of behavior and because of their real-world consequences. Several collections of slips are examined and an outline for a theory of action is proposed, based on selection of appropriate schemas, their activation in memory, and triggering by appropriate conditions, with errors possible at each stage. A categorization of slips is presented based on this outline. Finally, the role of feedback and cybernetic theories of human performance are discussed.

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Abstract

A slip occurs when a person does an action that is not intended. Slips have importance for both theoretical and applied reasons. They provide insight into the possible underlying mechanisms, and because they are errors of behavior, they have consequences in the world, some humorous, some embarrassing, and some tragic when they occur during the conduct of dangerous tasks. In this paper I examine several collections of slips, primarily of actions, with the aim of devising a theoretical explication. I propose that the path from intention to action consists of the selection of an appropriate set of schemas, their activation in memory, and then the appropriate triggering of the schemas when the conditions match those required for their operations. Errors can occur at each of these stages. The analysis of slips provides an outline for a theory of action based around the activation and triggering of schemas that specify the components of action sequences. From this outline it is possible to categorize slips into three major categories and a number of subcategories: (a) Errors in the formation of the intention (which includes mode and description errors); (b) Faulty activation of schemas (which includes capture errors, data-driven and associative activation, loss of intention, and misordering of action components); and (c) Faulty triggering (which includes spoonerisms, blends, intrusions of thoughts, and premature triggering). Finally, it is necessary to consider the role of feedback and the problems of differing levels of specification of an action sequence in order to understand the monitoring of behavior that allows some slips to be detected. This gives rise to a discussion of the role of cybernetic theories in the study of human performance.

Slips of the Mind and an Outline for a Theory of Action

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Prologue

I was touring in Europe several years ago, wandering through streets, camera on its strap around my neck. This particular camera had a built in exposure meter, with a small button near the center of the camera top that was both the on-off switch for the meter and the indicator that signalled that the meter was on. As I was walking, I glanced idly down at the camera and noted that the exposure meter was on. Without paying much attention I reached down with my right hand to turn off the exposure meter and instead put my finger on the shutter release button and took a picture. The resulting click caused me to stop, look down at my camera and ask "Why did I do that?" I thought the mistake interesting enough that I immediately wrote down what had happened, and started to think about its implications.

This incident started me off on a series of studies and observations. One direction led me to think about the nature of a processing system that could make errors of this sort. This investigation is still continuing, but it has led directly to a conceptualization of the role of a description in the retrieval of information from memory (Norman & Bobrow, 1979). A second direction was to lead me to the study of human motor control. The third direction was to continue the study of slips, especially slips of performance and actions (as opposed to slips of the tongue). All three of these lines of research are intimately related, as this paper will show.

For a year I have collected performance slips. Whenever I observed one, I immediately wrote down what happened, usually asking the people who made the slip to provide additional information, such as what they were thinking, and if they themselves noticed the error, how they came to notice and what their explanation would be (I do not necessarily believe their explanation). I enlisted my students and colleagues into the act, and my collection reached reasonable proportions.

One of my students started his car engine in the daytime and then intended to put it in gear: instead he discovered that he had turned on the lights. I was in a hotel restaurant when the check came. I signed my name to it, but couldn't remember the number of my hotel room. So I looked at my watch. The incidents go on and on. Some are amusing, such as the person who put the salad into the oven and the cake into the refrigerator and didn't discover the errors for several hours. Some slips are tragic. A performance slip in an aircraft can -- and does --

lead to aircraft crashes. Pilots have noted a problem in one engine and then, when meaning to shut it off, shut off the healthy engine instead. Fitts and Jones (1947a,b) record 730 such errors, some of them fatal. Reason has recorded others (1977, 1979). And I have talked with flight instructors and experienced pilots, many of whom have told me about incidents that either they themselves took part in or that they have seen others make: push the throttle instead of pulling it; retract the flaps instead of the landing gear; turn a switch on instead of off; navigate from the wrong map; land on the taxi strip of an airport instead of the landing strip, or at the wrong airport. Slips can be serious business.

Slips: Window to the Mind

A slip occurs when someone performs an action that is not intended. Slips do not occur randomly. They often result from conflict among several possible actions or thoughts, or by intermixing the components of a single action sequence, or by performing an appropriate act in some inappropriate way. It is my belief that errors can be interpreted by a suitable understanding of how people come to their intentions, and how that intent then becomes translated into action. Freud knew this, and from his analyses of errors, Freud made important contributions to our understanding of the mind. Freud's contributions have been severely undervalued by contemporary scientists, possibly as a reaction to his apparent overinterpretation of slips.

Freud's contribution can be reinterpreted. I believe Freud confused two different aspects of cognitive machinery: mechanism and knowledge. Freud believed that slips resulted from competition among underlying mechanisms, often working in parallel with one another, almost always beneath the consciousness of the owner. The resulting notions were of mental operations controlled by a quasi-hierarchichal control structure, with parallel activation of thoughts and memories, with conscious access to only a limited amount of this activity. The ideas are sophisticated even for today's theorists who only recently have introduced the differences between conscious and subconscious processing into their models of cognitive functioning. (We still do not know how a layered system of independently operating computational units might work.) Freud also was concerned with the particular knowledge contents of the memories and beliefs of his patients. I believe that it is this aspect of Freud that is most controversial, for like most of my colleagues, I believe that he went far beyond reasonable bounds in attributing vast influence from hypothesized belief structures.

Slips are indeed compelling sources of data. To Freud, the interpretation of some were clear, "for the meaning in them is unmistakable, even to the dullest intelligence, and strong enough to impress even the most critical judgment" (Freud, 1924). The examination of any large collection of slips reveals that they are not random occurrences. They can be categorized. They fall into patterns. (See, for example, the appendix in Fromkin, 1973.) Moreover, if one attempts to determine what possible mechanism could lead to such patterns of errors, the

result requires autonomous, subconscious processing, with intentions, past habits, thoughts, and memories all playing some role in corrupting the intended behavior.

On the Interpretation of Slips

Consider the following slip. I was the discussant on a paper by a distinguished psychologist. I had no advance notice about the contents of the paper, and so was forced to prepare remarks as the paper was presented and to continue planning the latter part of my remarks even as I started to say the first part. The conference was on the topic of knowledge representation and the speaker had presented us with some observations from experiments in visual perception, along with some theoretical interpretations. His interpretations are well-known, and quite controversial, at least within this audience. I deliberately wished to downplay the controversy and to emphasize the positive contributions of the talk to the issues of the conference. At one point, however, I said, "... this tells us nothing of the reputation (pause) <u>representation</u> of the information." (And one of my colleagues in the audience gleefully recorded the slip for my files.)

Freud would have nodded wisely and stated that my slip revealed my underlying concern about the reputation of the speaker (and another of my colleagues, afterwards, presented such an interpretation to me). That may very well be so, but note that the slip itself didn't occur at a random time: the hidden intent must have been sitting around waiting for just the right opportunity to reveal itself, a situation where the syntax and phonological components would match properly. The words "reputation" and "representation" share a common ending, a common beginning, and a common part of speech. These different aspects of a slip point out an important point: <u>most slips have multiple causes</u>. Freudian forces may indeed operate, but they do so in conjunction with other underlying forces, so that the resulting slip is multipli-determined, consistent with a number of constraints and explanations.

Analyses of verbal slips — and hundreds have been analyzed by other investigators (see Fromkin 1973, 1979) — indicate that the pronunciation of words is not a unitary concept associated with the words. Otherwise, once having started a word, we should go all the way through with it. But people say such things as "canpakes" for "pancakes" and "relevation" for "revelation." Or they interchange sounds among several words, as in "the sweeter hitch" instead of "the heater switch." And then there are blends, when in indecision between two words, out comes a mixture, as in "momentaneous" for the mix of "momentary" and "instantaneous" (all these examples come from Fromkin, 1973, Appendix). There appears to be the notion of individual parts of an action or of an utterance, perhaps differentially activated, waiting to be picked up and executed. My slip of "reputation" for "representation" probably had several contributing causes, with the actual word selection influenced by a combination of syntactical considerations, meaning, and phonological selection from the set of possible words, and perhaps other factors such as Freudian-like activation of my underlying motives and

plans for the commentary. None of these things individually would suffice to cause this particular error. It took the whole ensemble of reasons.

Some slips seem to result from the triggering of a well-formed habit in inappropriate circumstances, as in the report by William James that "very absent-minded persons in going to their bedroom to dress for dinner have been known to take off one garment after another and finally to get into bed, merely because that was the habitual issue of the first few movements when performed at a later hour" (James, 1890, p. 115). Other slips seem to result from "activation" of thoughts that are not intended to be said or performed. Sometimes these thoughts get done, with verbal slips leading to embarrassment and action slips to difficulties. Sometimes the complementary error occurs. Having thought about the need to do some action or to say some utterance, the deed is not done, but the person believes that it has been done (or, at least, later remembers it to have been done). If the former slip can be called "thoughts cause actions," the latter can be called "thoughts replace actions."

One important aspect of slips is that of error correction. Many of the errors are caught at the time they are made. Sometimes errors are caught just prior to their occurrence, but with insufficient time to prevent the act, or at least the initial stages of the act. For an error to be started, yet caught, means that there must exist some monitoring mechanism of behavior, but a mechanism that is separate from that responsible for the selection and execution of the act.

In the rest of this paper I examine slips and related issues in order to derive mechanisms that might give rise to them. In the process of studying the slips, I have been forced to consider a much wider set of issues than I expected. The understanding of slips has led to a theory of action.

Outline for a Theory of Action

Much in our everyday activities is controlled by subconscious mechanisms. We are quite unaware of how we perform our routine activities. Even that most cognitive of functions, language, resides primarily in the subconscious. As we speak, we often have little awareness of the words that will be spoken until just prior to their utterance. Even when I consciously search for a particular thought, I am aware primarily of a feeling of effort, or of will, or desire, not of a conscious selection among possible words or phrases. The times when I prepare an utterance with care prior to the speaking are rare, usually reserved for some special occasion where the exact words are critical. Then, the process requires considerable effort and mental rehearsal of the items: conscious preparation is the unnatural state. (It also occurs when I speak in a foreign language, reflecting my lack of skill in that language.)

Intention, Will, Schemas, and Consciousness

I propose that skilled action sequences are controlled by sensorimotor knowledge structures: schemas. By schemas, I mean organized memory units, much along the lines my colleagues and I have previously proposed for perception and memory (Norman & Bobrow, 1976; Rumelhart & Ortony, 1977). The extension of these ideas to include motor actions seems natural, both from the demands of the situation, and from historical precedent (Head originally introduced the term "schema" specifically for motor action — see Bartlett, 1932: also see Schmidt, 1975, 1976).

I assume that motor schemas receive activation from a variety of sources. Current context and semantic relevance both tend to increase the strength of activation of schemas. Primary memory serves as another component of activation: those things that we hold within the working memory and that guide our conscious thoughts and processes are all highly activated. (Here, I am equating the common notion of working memory and short-term memory, under the term "primary memory.") All these activations summate and then are dissipated when the original excitation source is removed. Actual selection of specific action components is made from among those schemas most highly active. Here are the germs of the capability for error, if thoughts, or semantics, or prior use of memory leaves a schema abnormally highly excited.

Consciousness. I propose that skilled actions — or actions whose components are themselves all highly skilled — are carried out by subconscious mechanisms. At our conscious level we need prepare only the high level selection of the act: we will an action and the lower level components of that action complete the story, to a large extent autonomously without further need for conscious intervention except at critical choice points. Wiggle the second finger of your right hand. Now wiggle the third finger. What did you do differently? Introspections are of little use. The difference is noticeable only in the intention: the actual selection of muscles was carried out at a level not subject to conscious inspection.

As I sit at my typewriter writing these sentences, my conscious resources are devoted to determining the intention: I then watch over the words as they appear on the paper. I do give conscious guidance to the forms of the sentences and to their higher level structures. I sometimes select particular words that capture the concept I wish to express, and then hold those words in consciousness while the sentence builds up on the paper, constructing an appropriate scaffolding. I am not normally conscious of the actual selection of words, nor of the activity of typing. I listen to my "inner voice" speak the words I write, and I watch them appear on the typing paper.

So too is it with other activities. When I drive home from the University, the appropriate schemas get triggered by previous actions, by the environment, by my perceptions. I need not consider the details: I intend only that I should drive home. Planning is required only if I wish to deviate from the normal route. Now, I must set up a schema to

be excited by some appropriate conditions along the way. Do I wish to detour to the fish store? I must have "fish store" actively in mind at the time I pass the critical choice point between home and the store. That level of specification is enough to set off the appropriate schemas to modify the route. Let "fish store" lapse from memory at the critical junction and I am apt to find myself at home, fishless. If I wish to deviate to go to a friend's home, much more conscious specification must be exerted, for the appropriate schemas do not exist at the highest level and I must therefore construct them: "When I get to the light at 4th Street, I must turn right, not left." Note that the deviation to the fish store or to the friend is just that: a deviation from a normal plan. If the relevant schemas for the deviation are not in a sufficiently active state at the critical time for their invocation, they are apt to be missed, and the normal plan gets executed by default.

Triggering conditions. More is required to select a schema than high activation, however. If activation strength were all there were to it, then it would be difficult or impossible to get the appropriate temporal ordering of sequences, as well as to avoid making a response that is being thought of, but deliberately not acted upon. Simple strength theories of selection do not suffice in studies of memory. The extra component needed for the schemas is a set of conditions.

To describe how schemas are activated and selected, I borrow from the considerable work that has been done on schemas in perception, memory, and learning, and on related work in artificial intelligence, especially the development of frames, agents, demons, and productions (Bobrow & Norman, 1975; Minsky, 1975; Newell & Simon, 1972; Anderson, Kline, & Beasley, 1979; Rumelhart & Ortony, 1977). In my view of schemas, they are active computational units, each seeking data relevant to their internal structure and organization. Thus, each schema has a set of conditions which are of interest to it. An activated schema can be triggered by current processing activity whenever the situation is relevant to it. There are a number of different possible theoretical specifications of schemas, but they are not important for our purposes. For current purposes, the important point is that there is selectivity of activation and triggering. The actual specification of an event involves the excitation of schemas at all levels and the specification of appropriate conditions that will trigger the motor control schemas in proper sequence. When an intention is formed, if it matches already existing schemas, then automatic schema activation will carry out the necessary levels of detail to specify the actual action.

This is a preliminary, high level statement of a theory of act selection. The details of the control exerted by the schemas is not presented. Do schemas control muscle positions, or tensions, or ratios of force-tension-length-velocity? Is there peripheral control and specification of the action? What kind of feedback monitoring is possible during the motor act? These are all questions that are under much active debate in the field of motor control, but which are not relevant to the general theoretical outline presented here. A final theory must account for these issues, but the slips under discussion in this paper

can be accounted for without these issues being decided.

Note that the specification of motor sequence can and should take considerable time. I have presented a model which requires many levels of activation of schemas, with information passing back and forth, with different levels of activation, with different degrees of specification of the final response. There is considerable experimental evidence in support of an extensive planning stage prior to a motor movement, a stage that seems to last between 150 to 400 msecs. During this planning stage (called the "reaction time," or the "refractory period," or the "latent period") there seems to be considerable cognitive involvement, as measured by the performance of the person on a second, subsidiary task during that time. Note that the response of the motor act itself does not even start till the end of this period. The length of the period seems to depend upon the complexity of the response being planned, even when the response is highly overlearned, well skilled (see Welford, 1968; Kerr, 1978; Sternberg, Monsell, Knoll, & Wright, 1978).

Application of the Theory of Action to the Interpretation of Slips

This model of schema activation is specifically designed to be consistent with the known literature on memory and models of schema-like computational mechanisms, as well as with the literature on the heterarchical nature of the motor control system. The model suggests several possible mechanisms for slips to occur. Note that the temporal units of a response are not all neatly pre-packed, lined up in some row or buffer memory, faithfully awaiting the appropriate time for execution. If this were so, then there would be little chance for error once the appropriate sequence had been determined. little chance for incorrect mergers of actions. Instead, many possible response sequences are often made available, and as each actual motor response is made, it sets up conditions for final selection of the next. Sometimes, an inappropriate unit will be selected when the conditions which would trigger it are closely approximated by the conditions which are present at the moment. Sometimes, a previously used unit will be re-excited when the conditions that trigger it are closely enough repeated. Sometimes the appropriate schema will fail to be triggered when either the proper conditions do not materialize or when its activation level drops too low: a memory loss. And, sometimes a completely inappropriate action will occur, whenever it has been activated for other causes, and an accidental match of the current situation with its triggering conditions occurs.

Slips can come in many different varieties. I have concentrated my collection and my analyses primarily on motor errors. However, I also collect verbal errors when they exhibit semantic properties or some interaction with planning or motor operations (planning errors are visible only in the case of typewriting or handwriting in which case the error involves the organization of the material on the page). In addition, I use the examples of motor slips collected by Reason (1977, 1979), in the book by Hurst (1976), and in official government accident reports. I have also used the collection of pilot errors by Fitts and

Jones (1947a,b), although a number of these errors are not relevant to the analyses that I am performing. In total, I have examined roughly 1000 incidents: 200 from my own collection.

The theory of action permits numerous opportunities for slips. There can be error in the selection of the plan, errors in the specification of the components. Even if the appropriate schemas are all activated, there can be errors of performance when schemas are triggered out of order, or when a relevant schema is missed. And then there can be errors resulting from the intrusion of unwanted activities from thoughts, or when some event occurs in the world that triggers an unintended response, or when a well-learned, familiar habit takes control.

The basic classification of slips has four major headings, each corresponding to a different aspect of act formation or performance, each contributing a source of error. These four major sources of action slips are: (a) the formation of the intention; (b) activation; (c) triggering; (d) carrying out the act. The complete classification is given in Table 1.

I. Slips during the Formation of an Intention

The formation of an intention is the result of many considerations, including the overall goals of the person, decision analyses, problem solving activities, situational analyses, and so on. Any or all of these can be faulty, but most are not within the focus of this paper. Here I start with intentions as given and therefore ignore errors that result from the decision-making or problem-solving aspect of intention formation. However, there are still two classes of intentional problems that do lead to relevant action slips, namely errors of situation classification and ambiguous or incompletely specified intentions.

On the whole, errors in the formation of an intention are difficult to classify, for their effects only shows up later, as the intentional specification filters down the system to the selection of schemas and the eventual triggering that leads to an action. Thus, to what should one assign the error of an incomplete or ambiguous intentional specification? Is it in the mechanisms that formed the specification? Perhaps not, for the specification is correct, simply not complete enough for the situation. In the mechanism that makes use of the specification in the selection of an action sequence? Perhaps, for this is the mechanism that actually does the deed that leads to the classification of an error. The blame is not entirely with this mechanism, but nonetheless, in this analysis, being forced to classify, I put the blame there. Ambiguous classification is therefore delegated to IIA and will be discussed later. This leaves us with only one class of slips to be analyzed under the category of formation of the intention: mode errors.

IA. Mode errors: erroneous classification of the situation. When a situation is falsely classified, then the resulting action is one that was intended and appropriate for the analysis of the situation, but inappropriate for the actual situation. There are a number of possible

Table 1

A Classification of Slips Based upon their Presumed Sources

I. Slips that result from errors in the formation of the intention.

- A. Errors that are not classified as slips: errors in the determination of goals, in decision making and problem solving, and other related aspects of the determination of an intention.
- B. Mode erros: erroneous classification of the situation.
- C. Description errors: ambiguous or incomplete specification of the intention.

II. Slips that result from faulty activation of schemas.

- A. Unintentional activation: when schemas not part of a current action sequence become activated for extraneous reasons, then become triggered and lead to slips.
  1. Capture errors: when a sequence being performed is similar to another more frequent or better learned sequence, the latter may capture control.
  2. Data-driven activation: external events cause activation of schemas.
  3. Associative activation: currently active schemas activate others with which they are associated.
- B. Loss of activation: when schemas that have been activated lose activation, thereby losing effectiveness to control behavior. This leads to such slips as:
  1. Forgetting an intention (but continuing with the action sequence).
  2. Misordering the components of an action sequence.
  3. Skipping steps in an action sequence.
  4. Repeating steps in an action sequence.

III. Slips that result from faulty triggering of active schemas.

- A. False triggering: a properly activated schema is triggered at an inappropriate time, leading to:
  1. Spoonerisms: reversal of event components.
  2. Blends: combinations of components from two competing schemas.
  3. Thoughts leading to actions: triggering of schemas meant only to be thought, not to govern action.
  4. Premature triggering.
- B. Failure to trigger: when an active schema never gets invoked, because:
  1. The action was pre-empted by competing schemas.
  2. There was insufficient activation, either as a result of forgetting or because the initial level was too low.
  3. There was a failure of the trigger condition to match, either because the triggering conditions were badly specified or the match between occurring conditions and the required conditions was never sufficiently close.

reasons for the misclassification, but the one I find of most theoretical interest for the purpose of this paper is a mode error. Here, there is some situation that can be considered to be an instance of a general class of related situations, with each instance a special mode of the general class. The name results from experience with computer text editors which have explicit modes for entering text (append mode) and for giving commands to the text editor (command mode). Failure to identify which mode the system is in leads to (frequent) errors of typing in text while in command mode or typing commands while in append mode. These errors can have serious effects: in one experimental text editor, typing the word of text "edit" while actually in command mode leads to destroying the entire manuscript or program, and then destroying the ability to invoke the normal "undoing" of such widespread damage. Similarly, many devices have visual displays or buttons whose meaning depends upon which mode the system is in. Failure to identify the mode correctly leads to erroneous interpretation of the display, or erroneous action. In all these cases, the intentions, the act specification, and the carrying out of the acts are done properly; the fault lies in specification of the situation.

The most numerous examples in my collection come from the use of our experimental laboratory computer. There are a number of different programs, each widely used, each of which requires the typing of text, but each of which has a different convention for ending the textual string. Thus,there are numerous instances of people inserting the "end-of-text" symbol required by the text editor into a message, or attempting to delete a file by using the editor command that deletes a line of text.

In other situations, one person reported attempting to move the carriage on his typewriter, by hand, while using an IBM Selectric typewriter that does not have a moveable carriage. Reason (1979) tells of a person who reported: "I sat down to do some work and before starting to write I put my hand up to my face to take my glasses off, but my fingers snapped together rather abruptly because I hadn't been wearing them in the first place." Reason also tells of the person who reported: "My office phone rang. I picked up the receiver and bellowed 'Come in' at it." From my collection there is the person who had been dictating for an hour with a hand-held microphone. He left the room to ask a question, then returned to complete the dictation. He picked up the telephone handset instead of the microphone.

As is usual, these errors can each have several causes. But they share the characteristic that an action entirely appropriate for the situation is being performed, except that this is not the situation current at the moment. Other sources may have contributed to the slips. Errors of partial specification seem also to be involved in the last example. The episodes of the bellowed 'Come in' and the removal of the non-existent eyeglasses could also be caused by capture errors (see later).

IB. Description errors: Insufficient specificity. Some slips of selection occur either when all the relevant information needed to form the appropriate intention is not available or when an appropriate intention has been formulated, but the description of the desired act is insufficient. This latter situation gives rise to what has earlier been called an incomplete description (Norman & Bobrow, 1979), leading to ambiguity in the selection of information from memory. These ambiguities can lead to such performance slips as the replacing of the lid to the sugar container on the coffee cup (both being similar shaped containers), or throwing a soiled shirt into the toilet rather than the laundry basket (again, both being similarly shaped containers: the laundry basket was in a different room than the toilet). Verbal slips frequently involve the substitution of one word of a related semantic field, such as "door" for "window," or "trampoline" for "hammock." Table 2 presents some of the motor and verbal errors of specification in my collection.

It is obvious that a number of the slips in Table 2 have alternative categorizations. Saying "I want you to be me" instead of "I want you to be you" has an obvious Freudian interpretation, and this could indeed be a contributing cause. The resulting behavior, however, is a substitution of one word for another, with both words being pronouns referring to the people in the conversation: the words differ only slightly in their specification, and if they were recovered from memory by an incomplete specification of the item, the resulting ambiguity would allow for this cause of error. This tolerance for word selection might then have been biased by factors such as assumed by a Freudian analysis, so as to select the erroneous word.

In general, the lack of selectivity only allows the slip to occur: it does not explain why this particular slip occurred. Unfortunately, in most of the situations analyzed here, there is insufficient information to determine what other factors might be operating. Note, however, that there are often severe restrictions that operate to select a word spoken in a verbal slip: there are syntactic class constraints, phonological constraints, and the semantic constraint that the selected word or action match the intention. Because words allow for rich semantic interpretation, there is much more tendency to attempt Freudian analyses of verbal slips than of the related motor action slips. But the same comments apply to them as well: lack of specificity only allows the slip to occur. Other factors might be present to affect the biases towards the particular event that did take place.

II. Slips That Result from Faulty Activation of Schemas

The activation of a schema can be faulty in one of two ways: a schema may be unintentionally activated, thereby causing an action to intrude where it is not expected; a schema may lose its activation before its appropriate time to control behavior has occurred, thereby leading to omission of its components of the action sequence.

Table 2

Slips of Selection: Description errors, or Errors in Specificity of Description

Situation and Intention	Action (or speech)
Eating bread. A's piece on plate, B's piece on counter (several feet apart). B intends to eat B's piece.	B picks up A's bread, bites into it, says "Oh my goodness, I'm eating yours."
Put toothbrush away in glass on counter.	Put toothbrush in hairbrush location: In cabinet, under counter, on opposite side.
Put lid on sugar bowl.	Put lid on coffee cup (same size opening).
Toss soiled T-shirt in laundry basket.	Toss shirt in toilet (different room than laundry basket).
Glass and coffee cup side by side (both empty). Intend to pour orange juice into the glass.	Pour orange juice into cup. Notice only when later attempting to pour coffee into the cup.
Intend to take rice from storage jar and measure in measuring cup.	Pour cooking oil into measuring cup: (both oil and rice kept in glass containers on counter top).
Turn on automobile engine. Intend to shift into gear.	Put on lights. (It was daytime.)
Intend to step on motorcycle brake (by depressing pedal with right foot).	Push gearshift lever (left foot).
Type a tab (large bar at top of keyboard).	Type space: large bar at bottom of keyboard.
Stop car, intend to unbuckle seatbelt.	Stop car, Unbuckle watchband.
Push button to turn off exposure meter of camera.	Push shutter button: take picture.
Intend to say: "You need a coin to turn that slot."	"You need a pencil ..."
Intend to say: "The only language they had in common was Russian."	"... English." (Observation recorded in Moscow)
Intend to say: "I am a sheep in wolf's clothing."	"...in lamb's clothing." (Said correctly by speaker 40 minutes previously)
Intend to say: "Speech is very much overspecified."	"... oversimplified."
Intend to say: "...new flight started to Amsterdam."	"...to Chicago."

IIA. Unintentional activation. Unintended activation of a schema can occur for several reasons, including the reasons discussed in section L (errors in the formation of the intention). More interesting, however, are errors that result from "capture," by data-driven activations, or by associations.

IIA1. Capture slips. The first major class of errors within this category is that of a capture error: when a familiar habit takes over. The basic notion is simple: pass too near a well-formed habit and it will capture your behavior. This is an interesting set of errors, best described by concepts from the traditional psychological literature on learning: strong habits are easily provoked. The mechanism is stimulus generalization. If the habit is strong enough, even partial matches from the situation are apt to activate it and once activated, it can get triggered.

A capture error is a form of error of activation, closely related to errors caused by thoughts or by external activation. Still, they have a certain flavor about them that set them off. I can do no better here then to quote Reason's eloquent description of this class of errors:

> "Like the Siren's call, some motor programs possess the power to lure us into unwitting action, particularly when the central processor is occupied with some parallel mental activity. This power to divert action from some intention seems to be derived in part from how often and how recently the motor program is activated. The more frequently (and recently) a particular sequence of movements is set in train and achieves its desired outcome, the more likely it is to occur uninvited as a 'slip of action'" (Reason, 1979).

The classic example of a capture error has already been mentioned: the example from James of the person who went to his room to change for dinner and found himself in bed. Here are two more examples, one from my collection, one from Reason's:

> "I was using a copying machine, and I was counting the pages. I found myself counting '1, 2, 3, 4, 5, 6, 7, 8, 9, 10, Jack, Queen, King.' (I have been playing cards recently.)"

> "I meant to get my car out, but as I passed through the back porch on my way to the garage I stopped to put on my wellington boots and gardening jacket as if to work in the garden" (from Reason, 1979).

IIA2. External activation (data driven). In the class I call "data-driven slips," the intrusions result from the analysis of external events: the environment forces an intrusion. This class is similar to the other forms of activation error, the distinguishing feature being

that there is some obvious environmental cause for the act. The most prominent example is the Stroop phenomenon, a classic demonstration experiment in psychology. Here, the names of colors (e.g., "blue") are printed in colors that differ from the name (so that the word "blue" might be printed with red ink). The task is to look at the word as rapidly as possible and say aloud the name of the ink color in which it is printed. There is extreme difficulty caused by the intrusion of the printed names. Here are some other examples of data-driven slips:

> "I had just given away my last cigarette. A smoker never lives with the knowledge that he does not have cigarettes available. At that time I did not have enough change to buy a pack from the vending machines. I went to my friend's room in the dormitories and got the exact amount needed to buy a pack of cigarettes. I went directly to the vending machines, put my money in and pressed the selection button. The pack was not delivered but the machine did not return my money. So I went to the laboratory to borrow some more money, and headed back to the vending machines. I intended to try a different selection button, hoping the machine would work this time.

> "When I got to the vending machines, I put twenty cents in the <u>coffee machine</u>, when I realized that I was there to buy cigarettes, not coffee. Since the money was not recoverable, I got the coffee even if I did not really want it.

> "I then went back to the laboratory, got some more change, and headed back again to the vending machines, this time successfully" (the story has been shortened from the original).

> "I was assigning a visitor a room to use. Standing in front of the room, at the telephone in an outside alcove, I decided to call the Department secretary to tell her the room number. Instead of her telephone number, I dialed the room number. (I knew the phone number well: for the past four years it was my phone number when I served as department chair.)"

<u>IIA3</u>. <u>Associative activation</u>. This class differs from capture activations in that there need not be any formal similarity between the action sequences involved, simply a strong association between them. Thus, the intention activates a relevant set of schemas which, by association to other schemas in memory, cause those others to become activated: this is the mechanism of "being reminded of." However, once the reminded of schemas are activated, it may be they that control the resulting actions rather than the intended schemas.

Errors of associative activation seem to occur most frequently in speech. One example occurred during discussion of the difficulty of viewing stars from the La Jolla/Del Mar area (because the nights are often foggy or cloudy): "You want to see stars — go to Lick Observatory. (Pause) Why did I say that? I was thinking Palomar. I was even

visualizing Palomar. (The speaker had lived for several years at Stanford, where the Lick Observatory is located, hence the strong association of "Lick" to the concept of "observatory.")

Similar examples are easy to find, such as the following conversation: "She stopped off in Cambridge, England. She used to live in Cambridge, Boston. Cambridge, umm, Massachusetts." Or the comment by a person while driving along the street of a town, looking for a place to eat, as they passed El Nopalito (a Mexican restaurant): "They have Chinee — Japa — Mexican food to go."

<u>IIB</u>. <u>Loss of activation</u>. When the appropriate schemas for an action schema are activated, some may lose activation as a result of the normal decay and interference properties of primary memory. The result shows up in several different ways, depending upon the exact schema that was lost and when in the temporal events of the action the schema was lost.

One result can be that of losing the desired intention, but allowing the behavioral repertoire to continue to its next logical junction. This led one of my informants to stand staring into the refrigerator wondering why he was there. Here is another, more complete example:

> "I have to go to the bedroom before I start working (writing) in the dining room. I start going there and realize as I am walking that I have no idea why I go there. Knowing myself, I keep going, hoping that something in the bedroom would remind me. ... I get there but still cannot recall what I wanted ... so I go back to the dining room. There I realize that my glasses are dirty. With great relief I go back to the bedroom, get my handkerchief, and wipe my glasses clean."

Sometimes the components of an action are misordered. Thus, a student reported the following incident:

> "I was at the end of a salad bar line, sprinkling raisins on my heaping salad, and reached into my left pocket to get a five dollar bill. The raisins knocked a couple of croutons from the salad to the tray. I reached and picked them up, intending to pop them into my mouth. My hands came up with their respective loads simultaneously, and I rested the hand with the croutons on the tray and put the bill in my mouth, actually tasting it before I stopped myself."

> Once while jogging with a colleague early in the morning, I reported my academic history as "I got my degree at Harvard and was a post-doc and faculty member at Penn." (Exactly the reverse of the facts.)

Another class of errors is to leave out a step in a sequence, such as to forget to put the water in the coffee maker. Studies of aircraft accidents (Fitts & Jones, 1947a,b) reveal that skipped steps are a frequent cause of accidents.

An obvious other class of error would be the repetition of a step in a sequence, or the restarting of a sequence at some earlier stage. I have observed people (and myself) engaging the starter of an automobile after the engine had already been started. (This could, of course, also be classified as a mode error.) However, no incidents of this sort are in my collection.

Reason (1979) does provide a number of examples however:

> "I started to pour a second kettle of boiling water into a teapot full of freshly made tea. I had no recollection of having just made it."

> "As I was leaving the bathroom this morning, it suddenly struck me that I couldn't remember whether or not I had shaved. I had to feel my chin to establish that I had."

> "I put a cigarette into my mouth, got my matches out, then instead of lighting the cigarette I took another one out of the packet."

III. Slips That Result from Faulty Triggering

A schema may be properly selected and activated, but lead to a slip because it is triggered improperly, either at the wrong time or not at all. The most famous examples of inappropriate triggering, leading to reversals of event components are spoonerisms, where components of words are interchanged (as in Spooner's example of "You have tasted the whole worm" instead of the intended "You have wasted the whole term.")[1]

One form of error is to blend the components of actions. Presumably, these occur when two or more active schemas are triggered simultaneously, sometimes resulting in the merger of two schemas that are indeed appropriate for the situation, sometimes merging a relevant schema with one that is not relevant (or, in the Freudian case, not desired). Blends sometimes result when a person is unsure of which of two actions to perform: the result is a mixture of both, as when indecision between the choice of the words "close" and "shut" yields the response "clut." Merges tend to involve activation and anticipation components, such as in the saying of "... financed by the Rockebrothers,

1. There is reasonable evidence that the Rev. Spooner's reversals were often deliberate, carefully planned and thought out. Thus, this example stretches credulity. Nonetheless, the basic phenomenon is real and simpler examples are well documented (see Fromkin, 1973, 1979).

uh, the Rockefeller Brothers Foundation", or in the following mixture of two related names when a prominent psychologist, giving a colloquium at my University commented on "... some interesting studies by Lynn Shepard." (The speaker did not notice the slip: Lynn Cooper was a student of Roger Shepard, and has published numerous joint articles with him.) A large class of errors occurs from false triggering of acts among the things currently active in mind. Thus, one can have an anticipation error such as "She presented these to American subjects and she presented these to Chinese — um, Japanese. I'll get to Chinese in a minute." Or, "Suppose you put a string around a ten-foot earth," where the intent was to say "ten-foot ball" but the speaker was simultaneously planning ahead how to talk about the problem of putting a string around the earth.

With a computer system, many errors come from doing the desired result rather than the action that leads to the result. Thus, because typing the "break" key terminates the program and leads to the appearance of the symbol "$" on the screen, several students have reported typing the "$" directly rather than the break key. (The $ sign is never used as a command in this particular computer.)

> "I was typing a note to some students, stating when I could meet with them. I was mentally reviewing my day as I typed. I had a lunch appointment at 12:00 PM., so I decided I could meet with them at 2:00 PM. I typed 'can we eat'. I then realized the error and changed the 'eat' to 'meet'."

> "One day as I was running on my morning trek, I saw a woman ahead. I was counting steps, but as I neared the woman I decided to say "Good morning." When I got to the woman, she smiled and said "Good morning," and I responded "thirty-three."

A related class of errors comes from confusing thoughts with deeds. Here is a lack of action rather than an intruded action. But the cause is related: an activation in primary memory was misused, in this case to substitute for the act.

> "I think of asking A to make more coffee, and later complain of the lack. My thought, it turns out, was never voiced."

> "I make an error typing a line on the computer, think of typing the special character that deletes the line ('@'), and then continue typing, only to find that the computer responds with an error message: the '@' sign was only thought, not actually typed."

Slips that result from failure to perform some action are more difficult to detect than errors that result from a falsely executed action. Indeed, if both the action components and the intention are forgotten,

there is little to signal either the person or an onlooker of the error. Slips resulting from failure to do something are common in experience, however, such as forgetting to mail a letter, or to stop at the bank on the way to work. Some of these cases are covered in lack of activation in Section II of the classification.

Cybernetics and Cognitive Psychology

The Need for Feedback Mechanisms in Cognitive Behavior

Many slips are detected by the perpetrator, oftentimes as the act is being initiated and before any real headway has been made for the discrepant behavior. Sometimes slips go undetected for relatively long periods, and sometimes they are never detected. I presume that some slips are caught so early in their cycle that they are unseen to the observer, and perhaps even unconscious to the producer.

A slip can be detected only if there is some form of monitoring mechanism capable of detecting a discrepancy between what is expected and what occurs. The task is non-trivial, for the specification of the intention is considerably different from the mechanics of the act. In order for discrepant behavior to be detected, two things are necessary: a feedback mechanism with some monitoring function that compares what is expected with what has occurred; a discrepancy between expectations and occurrences.

The existence of feedback mechanisms seems a logical necessity in the control of human behavior (or almost any complex behavior, animal or machine). In cognitive psychology, feedback mechanisms have played almost no role, probably because the emphasis has been on the reception of information rather than the performance of acts. Despite the central use of feedback in the widely cited book _Plans and the structure of behavior_ (Miller, Galanter & Pribram, 1960), and despite the development of cybernetic theory, one can search the cognitive journals and texts in vain for any discussion of the topic. Those areas of psychology that study output — manual control, human factors, and motor skills — do worry about feedback, but there has been little interaction with cognitive psychology. The study of slips produces the serendipitous property of merging these two different worlds of analyses: the sensory-perceptual-intellectual world of the cognitive psychologist and the cybernetic-feedback control systems of those who do study motor systems. The analysis of slips requires study of the intersection between the cognitive control system and the motor control system.

Some Examples of Error Monitoring

Many, but not all, of the errors in my collection of slips were caught by the perpetrator. (Unfortunately, the importance of knowing how a slip is discovered is not commonly recognized, and in most collections of slips, this information is not recorded. Even in my own collection, this information is not always available.) Slips are caught at various levels of action, from the start of the activity to after

considerable delay. Table 3 presents examples of the catching (or failing to catch) of slips at different points in the act. Note that many of these slips are caught only with the active cooperation of the observer, or the listener. And sometimes even the cooperative effort fails. With motor slips, at times the slip is discovered only because the incorrect action leads to a situation that reveals itself later. Thus, one subject reported pouring orange juice into the coffee mug, drinking the juice, and noticing the problem only when desiring to pour a cup of coffee, and the remnants of the juice attracted her attention.

Note the critical point of the feedback analysis: for a slip to be detected, the monitoring mechanism must be made aware of the discrepancy between intention and act. But if the monitoring function only has access to the act specification, it can only say how well the act is performed, not if it is the correct one. The following example demonstrates a form of error that was not detected by the speaker:

> _A_ was driving a van and noticed that the rear view mirror on the passenger side was not adjusted properly. _A_ meant to say to the passenger on the right "please adjust the mirror," but instead said "please adjust the window." The passenger, _B_, was confused, and asked "What should I do, what do you want?" _A_ repeated the request: "Adjust the window for me." The situation continued through several frustrating cycles of conversation and attempts by the passenger to understand just what adjustment should be made to the window. The error correction mechanism adopted by the driver was to repeat the erroneous sentence more and more loudly.

The apparent difficulty here is that the feedback monitoring was at the wrong level to detect the failure in the word selection. Instead, it attempted to correct failure in word enunciation. Suppose that _A's_ intention had been imprecisely specified as "to adjust that ill-specified object on the right side of the van," and suppose that this intention had spawned a set of schemas and action units that eventually chose "window" as the name of an object on the right side of the car. This would lead to a failure to detect the error, for whatever mechanism monitors the spoken word would accept "window" as appropriate (assuming it was indeed pronounced properly): both "window" and "mirror" fit the same, ill-specified description. (The error itself is possibly also a form of intrusion slip, for the window was in the visual path to the mirror, and the sight might have helped select the incorrect word. Whatever the cause, the point is that the error was made at a level undetectable by the monitoring function.)

Levels of Feedback Systems

In the classic feedback control system, there are two fundamental parts: a forward control cycle in which the input to the control system specifies the output and a loop back in which the output is compared with the intention. If the forward component of the system were used

Table 3

Examples of Detecting Slips at Various Stages in the Action

Caught in the Act

"I was about to pour the tea into the opened can of tomatoes that was just next to (left of) the teacup. (The can was empty.) Not yet an error — but certainly a false movement."

Caught Just after the Act

"One of the problems with the TV guide — the TV guide — the restaurant guide."

"Financed by the Rockebrothers, uh, the Rockefeller Brothers Foundation."

Multiple Corrections

"This is paid for by NSF, I mean CHIP, I mean Sloan."

"I think it's time he cleaned up his office, too. Umm, desk, umm room."

"They have Chinee – Japa — Mexican food to go."

Not Caught (by the Perpetrator)

A: We're not very good at badminton anymore.
B: What?
A: Badminton
B: Badminton?
A: Oh, I did say badminton, didn't I. Table tennis.
B: Where did that come from?
A: I was thinking about planning the yard, and thinking of putting in a badminton court.

"I told the water skiing story in which the skier is almost hit by another boat. I said: '... almost hit by another car.' A listener interrupted to point out the error. I was skeptical, but another listener confirmed the error."

Caught after a Very Long Delay

A notices that B is using his special (and expensive) scissors with serrated blades to cut some loose threads from clothes. (Both A and B had agreed that the scissors was reserved for trimming hair.)
A: Hey -- No! That's a hair comb.
B: Oh -- sorry.
The normal activities then continued. There was no further conversation. B went and got another scissors. About a minute or two after the conversation:
A: I meant that was a hair scissors, only to be used to cut hair.
B: I know what you meant. I did have the vague feeling that something was wrong, but I wasn't sure what. Now I realize that you called the scissors a comb. I understood you though.

alone we would have the basic sequence of "intention" to "selection" to "action." Because a sequence of this sort has no feedback loop, it is called "open loop control." In a feedback system, the output action is compared with ("fed back to") the intention, and any discrepancy between intent and act is used for further input to the selection mechanism. Hence, this is a "closed loop" system. (In a negative feedback system, it is the difference between the two that controls further action. In a positive feedback system, the goal is to increase the response even more, and so the output act is added to the intention and then used to control the selection. In the traditional feedback control system, both intention and action are specified by continuous variables — such as the real numbers, or electrical voltages or mechanical shaft or linkage positions — and the comparison process does an actual subtraction when there is negative feedback, addition when there is positive feedback.)

In the terms used in this paper, the basic control sequence is from intention, to selection, to action. The selection mechanism involves all that was discussed in the section "A theory of action"— the specification and activation of schemas and the eventual triggering of a motor control schema that produces an act. Note that the only way that an error can be detected is for it to occur within the action selection mechanism, or in the actual mechanics of performing the response. If the intention is incorrectly specified, the error cannot be noted, not by this system, anyway. The basic feedback system just discussed is appropriate for the detection of discrepancies in acts and intentions, but it is otherwise inadequate. There is much too large a difference in the level of specification of the intention and the actual acts that get done: the comparison mechanisms would have to be horrendously complex. When my intention is to drive home, one of the acts I perform along the way is to move my right hand down while simultaneously moving my left hand up. (I am rotating the steering wheel of the automobile in order to leave the parking lot.) The difficulty is that the intention is specified at a very high level of abstractness, whereas the act is specified either in terms of muscle signals or limb movements. To do the comparison between intentions and actions, the two must be at the same level of specification.

Consider the problem of language behavior. The intention is specified at some abstract "idea" level, but the output of the motor control system is the production of sound waves. To match how well the sound conveys the idea requires the monitoring function to go through the whole process of speech understanding, first to identify the words that have been spoken, then to determine if the interpretation of those words matches the intention. This kind of comparison would hardly do to correct the pronunciation of a word midway through its utterance, or even to correct the choice of word.

The action system must have many feedback comparison processes, each looking at different levels of the operation of the system. In speech, at some low level, feedback processes probably monitor how well sound frequencies and intensities match the intended voice pitch and loudness. Other systems probably monitor rhythm and stress, intonation

and pronunciation. A different system must compare the intended word selection with that actually being uttered (or triggered for utterance), and so on: different levels for different purposes.

With motor actions, similar division among levels is required. At the peripheral muscle control system, feedback loops are needed to monitor the arm and leg movements, with the loop probably being self-contained in the peripheral nervous system. Even at the level of skilled movements, there are numerous different feedback systems. The moving of the hands in the earlier example is intended to rotate the steering wheel. The rotation of the steering wheel is intended to cause the automobile to turn sufficiently to avoid an obstacle. The avoidance of the obstacle is intended to allow the automobile to proceed on the course towards the exit of the parking lot. Exiting the parking lot is intended as the first leg of the trip home. Each level of specification of the intention must be decomposed into more basic levels in order for an action to take place, each new decomposition more finely dividing the actions required, more precisely specifying what must be done. And each new level of specification is, in turn, decomposed into its basic components, until some primitive level of act specification is reached. The scheme is <u>not</u> a hierarchy: it is a spawning of independent action systems, each complete with the possibility of feedback monitoring of its own performance. Each system is a schema, with the decomposition process being the activation of schemas, the feedback mechanism being the attempt to satisfy some of the internal conditions required for triggering (or the cessation of triggering) of the schema.

There are some restrictions on the form of feedback analysis. Thus, a major controversy within the motor skills area has been whether such acts as the control of the peripheral limb is done with feedback (closed loop) or without (open loop). There is good agreement that peripheral feedback mechanisms do operate at the level of muscle control and that higher level feedback does monitor the total activity. The issue is whether there can be immediate feedback control of the individual movements, the major contention being over the issue of the time that would be required to send feedback control signals around the loop while doing rapid, skilled acts. Resolution of this issue is not critical to the application of the general ideas discussed in this paper. Whether the feedback control of individual movement is fast enough to correct for errors as they happen, or whether it must initiate corrections with some reasonable time lag, are issues to be determined by empirical investigation.

<u>Comments on Naturalistic Errors</u>

The collection and analyses of naturally occurring errors forces us to consider real behavior, unconstrained by the limitations and artificiality of the experimental laboratory. By examining errors, we are forced to demonstrate that our theoretical ideas can have some relevance to real behavior. There are situations that are simply too complex to be reproduced in the laboratory: naturalistic observations carried out accidentally are the only way to obtain data of people under extreme

stress (in some cases, while they face severe injury or death during an emergency situation).

But naturalistic observations have disadvantages. It is difficult — sometimes impossible — to record exactly what went on. Observers are not always around, and even when they are, they are not always ready to make the detailed observations that would be required. records from memory (and even from direct perception) are notoriously unreliable. I have found that when even a minute separates the observation of an error to the start of the recording of that error, details have begun to slip away. At one point, a colleague who also collects errors and I both observed an slip, and both of us wrote it down independently almost immediately thereafter. Our two accounts differed in the details (although we agreed upon the the essentials).

One common question about these errors concerns their frequency of occurrence, both with respect to each other (relative frequency) and in absolute terms (absolute frequency). Naturalistic observations cannot be used to determine these numbers. I have not provided percentages for my observations because I believe that the numbers would be misleading. Observers are selective in what they record. It is sometimes difficult to determine what should count as an error. And I (and my colleagues) sometimes get lazy, saying, "Oh no, not another capture error: Don't I have enough already?" Well, if the goal is to collect a general sampling of all forms of errors, then yes, a few examples of each category will suffice. If the goal is to determine relative frequency, then only the complete record will do. I believe that accurate sampling and statistics can come only through video recording of large segments of behavior, and then careful perusal of the tapes in order to transcribe in detail the situations identified as errors (see Deese, 1978). Mackay has argued that naturalistic data can be used to give reasonable statistical estimates when "a strong case can be made that the missing data are random or unselected with regard to what you're analyzing" (Mackay, 1973; also, personal communication).

<u>Bringing the Errors into the Laboratory</u>

The study of errors has several important consequences. First, it causes us to re-evaluate our theories. Second, errors occur in public situations where lives can be put to risk as a result. It is of extreme interest to people who control such services as the transportation systems to minimize errors. Aircraft deaths have been attributed to errors by pilots, or crew, or service people. If we can understand the causes of these errors and minimize their occurrence (either through retraining or equipment redesign) the quest will have been worthwhile.

To validate what has been theoretically postulated as the cause of errors, laboratory tests are useful. I believe it should be possible to cause many of the errors in my classification scheme to occur within the experimental laboratory. Errors of activation and of capture seem especially likely to be reproducible. MacKay, Baars, and Motley (see bibliography) have been quite successful in generating verbal errors in

laboratory situations. I believe their techniques and others can be adapted to the study of motor behavior.

Summary

Slips of word and deed cry out for interpretation. The errors are revealing of hidden intentions and mechanisms. In this paper, I have attempted to draw from a reasonable collection of slips sufficient components and constraints for a theory of action and and its essential cohort, a cybernetic theory of monitoring. The nature of the errors seems such that simple serial buffer models will not suffice, but rather the individual components of an action must compete for their turn to be executed. Each activated component is a sensori-motor schema, with conditions that specify when it is to be triggered into action. Were this all there were to the theory, the only errors that could occur would be errors of ordering, in which a relevant component missed its triggering situation, or an erroneous one was mistriggered when the existing situation provided a sufficient match for its trigger conditions.

But the theory allows for multiple sources of activations, for example from the external world (data-driven activation), or from internal processing (thoughts, associations, prior or future action components), or by capture by well learned familiar habits. The likelihood that a given schema will be triggered is a joint function of its level of activation and of the match between the goodness with which the current conditions match the triggering conditions. This tradeoff provides an obvious place to develop experimental tests of the theory.

The basic theory is multi-leveled, with each level capable of exciting other levels. The major levels are those of intentions which in turn spawn schemas. Schemas exist at several levels of specification, from the general to the most specific movement of the limbs. Schemas are activated by the conscious formation of the intentions and plans that specify them, or by being a component of an action-sequence. Schemas are also activated when brought into primary memory, whatever the reason, be it for memory search, by association, or by current thought processes. The degree of activation reflects the degree of relevance of the current information, the total number of sources of activation, and the recency of past activations. Schemas at the highest level of specification of an action activate lower level (more specific) schemas, that are appropriate to the particular action being organized. Finally, schemas are triggered by an appropriate set of conditions, thus leading to the actual response.

Conscious awareness of the schemas is not necessary for performance. The general idea is that well-learned action sequences need only be specified at the highest level. It is only with poorly learned acts or with novel re-arrangements of well-learned components that conscious awareness of lower level components is required. When an action sequence is modified, however, then there is a critical junction point at which the modification must occur, and if the required schema is not activated at that time, the regular, unmodified act will continue. Some

errors occur when there is loss of components from memory. Depending upon what is lost, the error may simply be a missed action, or an erroneous sequence, or reversion to a prototype act, or if it is the conscious level of intention that is lost, the result may be to wonder what the purpose of the current actions are.

Feedback plays an essential role in complex behavior. With slips, it is of interest to discover under what conditions a slip can be discovered and when it cannot. The monitoring of actions is a basic component of a feedback control system, but the monitoring function requires that the comparison of intention and action be done at the same level of specification. Because complex acts have many differing levels of specification, each with their own relevant schemas and operations, the monitoring function must also be performed at many different levels. The performance of an action, from initial conceptualization through realization is then the process of decomposing the original intention into a sequence of physically performable acts, with multiple levels of feedback analysis accompanying the acts.

Bibliographic Notes

Slips

When I started my collection of slips, I thought I was alone, that I was embarking upon new ground. Of course I knew of Freud and of slips of the tongue, and of Spoonerisms, but I was not aware of systematic collections of errors. This note reveals the studies that I have found, much more copious than I had imagined. I hope the note will be useful to others interested in pursuing these studies. It may also serve to reveal deficiencies in my knowledge.

By all means start with Fromkin. Her two books (1973, 1979) provide the most copious analyses of speech errors around (with a sprinkling of other modalities). The appendix to the 1973 book provides a good collection of speech errors. Most of the older relevant literature is either recorded there or cited. Then go to Freud, most especially his works on the "Psychopathology of everyday life" and Part I (called "The psychology of errors") of his "General Introduction to Psychoanalysis" (part is reprinted in Fromkin, 1973). Clark and Clark (1977) have a chapter on speech errors, which can also provide an introductory level approach to the literature.

Perhaps the largest and most complete collection of errors is that collected by Rudolf Meringer (1859-1931), alas, in German, but see Celce-Murcia, in Fromkin (1973). One of his books (Meringer, 1895) has just been re-issued. The introduction to the re-issue was written by Cutler and Fay (1978) and I find that an excellent review and source. Meringer's corpus provided some examples for Freud, but they disagreed on the interpretations so much that any possible collaboration never materialized. Freud (1924) says of Meringer and Mayer (1895), that their explanations are "peculiarly inadequate" (p.37).

Fay has collected a corpus of 5000 errors (Fay, 1978, 1979a, 1979b). Fay states that "in each case, the error was written down at the time of its occurrence, along with as much linguistic and situational context as seemed relevant. When possible, the intended utterance was determined by querying the speaker; otherwise it was determined from the linguistic context, including, most often, the speaker's spontaneous corrections" (Fay, 1978, Footnote 3).

MacKay's work has proved particularly interesting, and his theoretical interpretations, at least in one source (MacKay, 1972) are very similar to my ideas of insufficient specification of description. The works of Baars and Motley are extremely important, for they have succeeded in causing many of the speech errors, especially Spoonerisms. In many ways, these are the most important works, for it illustrates a bridge between the naturalistic observations and laboratory work.

Motor Errors

There is not much in the literature on motor errors. The most important analyses of motor errors are by Reason, whose work provides many unique examples of motor errors, some of which have important practical consequences. Reason's explanations differ from mine in that he emphasizes the calling procedures and specification of the subroutines of motor controls. This is a formulation that overlaps mine in many ways, but has as its basis quite a different model of the underlying processing and control mechanisms. Reason's papers have been of considerable value to me, both in supplementing my collection and in the suggestions of possible theoretical mechanisms.

Fitts and Jones (1947a, b) analyzed pilot errors, 460 errors in operating aircraft controls, and 270 errors in the reading and interpretation of instruments. The book Pilot Error is a useful source of some information, but despite its title and obvious relevance, it has surprisingly little information (Hurst, 1976).

Motor Control

Within the field of motor control, hierarchical (and heterarchical) control mechanisms are standard fare, and the need for feedback is assumed. The work here is consistent with much of the existing literature: it should not be assumed that the development of hierarchical control theories is anything new. To my knowledge, however, the issues have never been addressed at quite this level before, the level of cognitive specification of an action, along with cognitive monitoring of the resulting performance.

The work by Miller, Galanter, and Pribram (1960) is clearly related to the current theory, and although I did not refer to this book until after I had completed the first version of the paper, I grew up within the spirit of the work described therein (and studied and worked with two of the three authors). Shaffer (1976) presents a model of intention and performance that is intended to cover typing, speech, and piano playing. His model differs from the one here in the specification of the control processes, with Shaffer suggesting buffers and pointer processes. His paper, though, is clearly an important predecessor to the development of the current theory.

There are three major sources and references that I have used in my development. First, the work by the Soviet psychologist Bernstein (1967) who pioneered the work of feedback analysis of movement, especially of large body movements. His "comb" theory is suggestive of the control processes described here. Second, there is the important analysis by Lashley (1951) of the problem of serial order. And third, there is the general review of organizational models of neural function by Szentagothai & Arbib (1975).

Acknowledgement

Partial research support was provided by the Office of Naval Research under contract N00014-79-C-0323, NR 157-437, and from the Advanced Research Projects Agency, monitored by ONR under contract N00014-79-C-0515, NR 157-434. Support was also provided by grant MH-15828 from the National Institutes of Mental Health to the Center for Human Information Processing.

I am thankful for the help of the LNR research group, both in the building up the collection of slips and in providing useful comment upon the analysis of the examples. In particular, Jonathan Grudin was an avid collector and analyzer of slips. His help is much appreciated. I appreciate the comments and help of various readers, especially Peter Lindsay, J. L. McClelland and George Mandler. Bernard Baars, Elliot Saltzman, and Dedre Gentner provided useful comments. I gratefully acknowledge Marigold Linton's living room floor.

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